Development of an Active Pixel Sensor Vertex Detector

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There is tremendous interest in ultra-relativistic heavy ion physics to measure open charm. Due to their large mass, charm quarks are produced almost exclusively from initial state parton-parton interactions. However, lighter quarks (u, d, s) may be produced in hadronic interactions. By this virtue, charm provides a more direct connection to the early stage without contamination from later phases. The total charm yield should be sensitive to the initial state, while the hadronic charm composition (J/ψ, D, D_s, Λ_c) will depend on the dynamical evolution of the system. With the help of a new high-resolution inner vertex detector, we will measure the charm content through the D meson, and possibly through the D_s and Λ_c.

Work [1] at LEPSI in Strasbourg has demonstrated that Active Pixel Sensor (APS) technology in CMOS is able to detect minimum ionizing particles. As APS technology is in its infancy, there are many outstanding issues to resolve to create a working high-resolution pixel detector.

We designed a prototype sensor array that includes an array of 128 by 128 pixels divided into four quadrants of 64 by 64 pixels. Each quadrant uses a different sensor structure and/or readout circuit. A pixel is 20 by 20 microns in size, and the entire array is about 2.5 mm on a side. Quadrant 1 has a single diode to pick up the charge from the chip while Quadrant 2 had four diodes. Due to the larger capacitance of Quadrant 2, the signal size is less than Quadrant 1. In this article, we will report on the results from Quadrant 1.

We mounted the APS chip on a readout board and used a 2 MHz pipelined ADC to digitize the data. A Xilinx XC3064A FPGA provided the control signals to read out the APS chip and sent the data to a National Instruments PCI-DIO-32HS PCI interface located in a Macintosh G3 computer. A 16 K x 16 FIFO chip between the ADC and the DAQ interface provided an elasticity buffer to guarantee consistent readout timing.

While the ALS was in the storage ring mode, the booster was used to deliver 1.5 GeV electrons to our detector at a rate of 1 Hz. We put our detector at the end of branch line off the main booster-to storage ring (BTS) transfer line.

To eliminate the noise introduced by resetting the chip, we analyzed the data using the correlated double sampling method. Assuming that all of the energy deposition is in the 8 μm epitaxial layer of the chip, we had excellent agreement with the expected peak energy distribution of 500 electrons. The measured noise was 17 electrons.

In the laboratory, we have been testing the chip to understand it. A second-generation chip has just been fabricated to improve its noise performance and will be used to optimize the CMOS parameters.

Footnotes and References

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1. *R. Turchetta* et al., *Nucl. Instrum. and Methods A* ***458****, 8 (2001).*

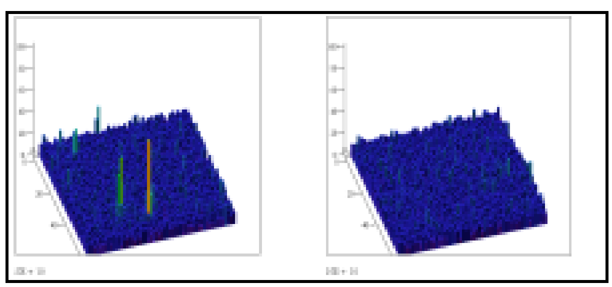

Fig. 1. The graph on the left shows the response of Quadrant 1 to 1.5 GeV electrons, while the graph on the right shows the results when the beam was turned off. Each rectangle represents one pixel on the chip. The height of each rectangle represents the energy deposited in each pixel.